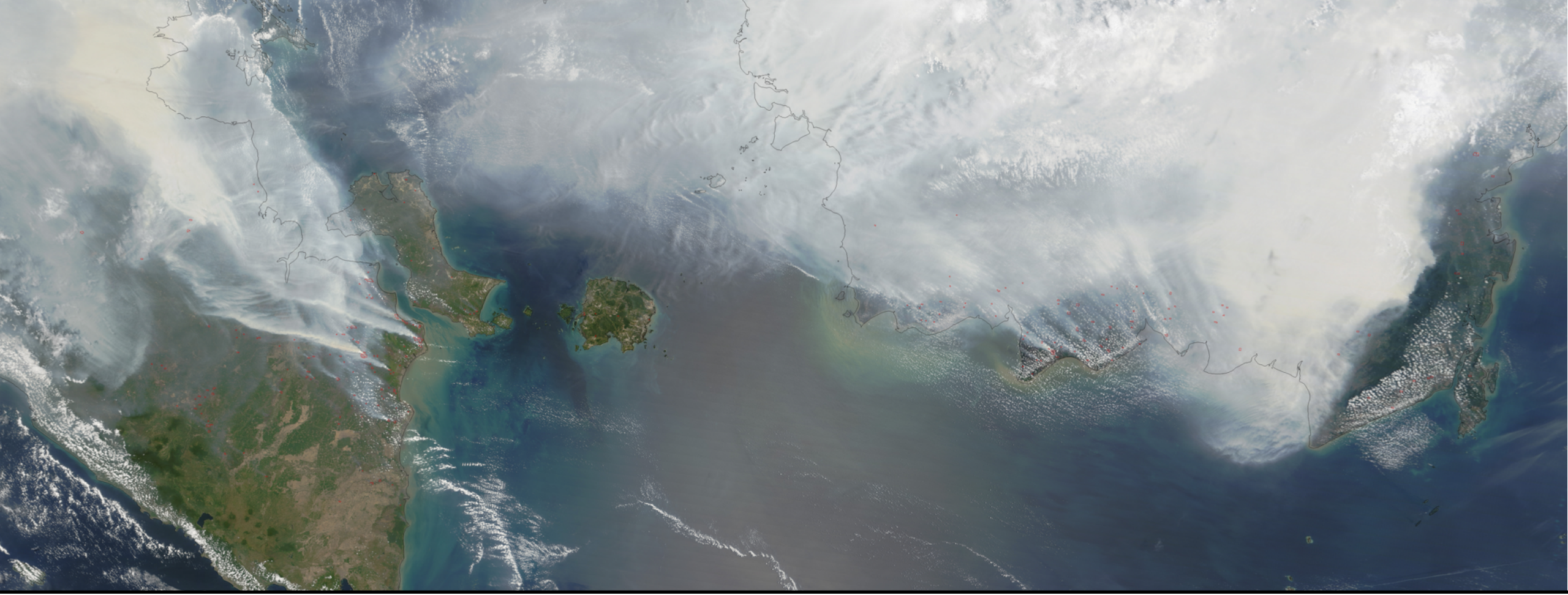


Near Real-Time (NRT) Volcanic SO₂, Geostationary, and the MERRA-2 Reanalysis

Pawan Gupta, Melanie Follette-Cook, and Bryan Duncan

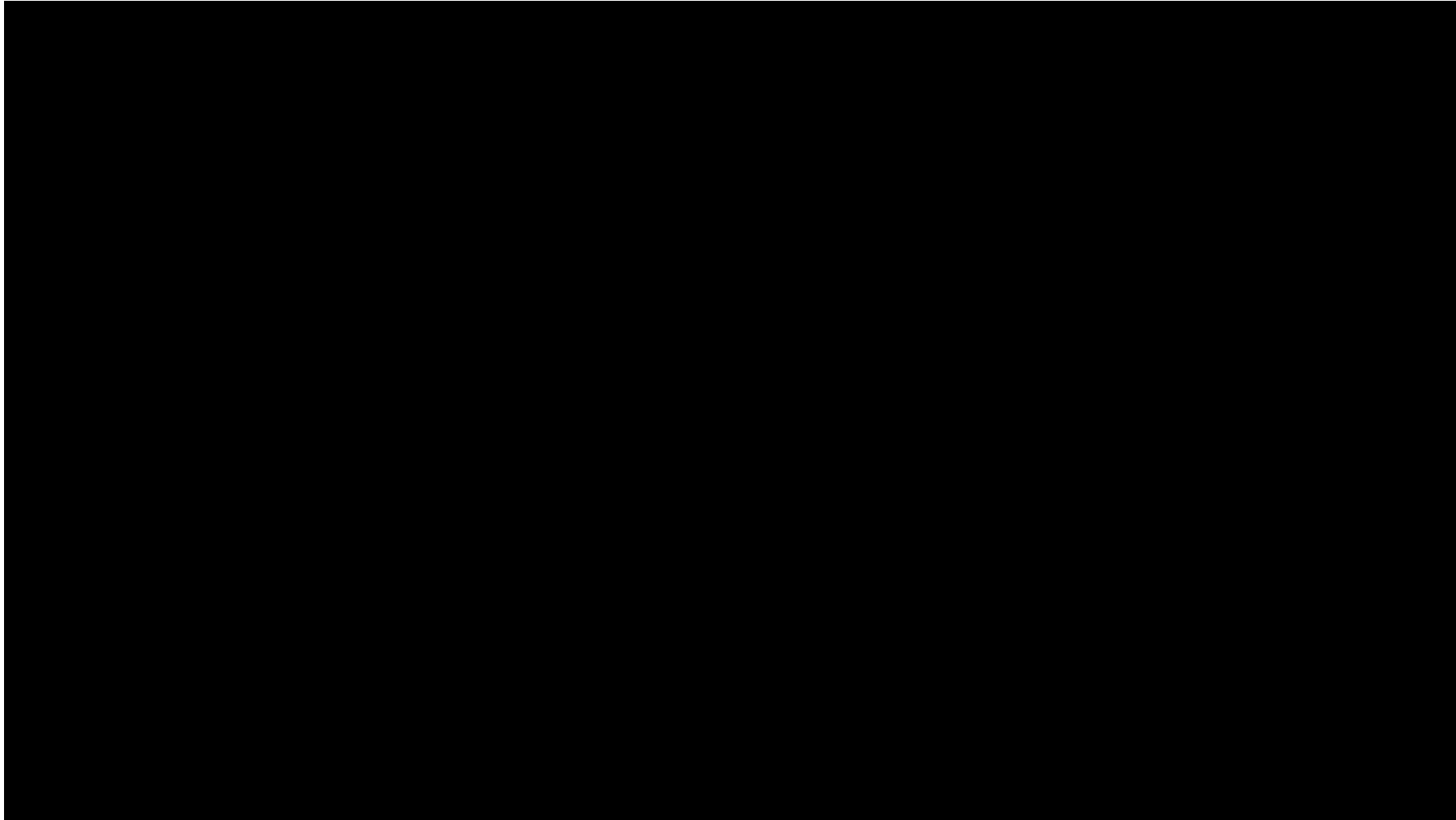
NASA Remote Sensing for Air Quality Applications, March 20-23, 2018, Jakarta, Indonesia





Volcanoes

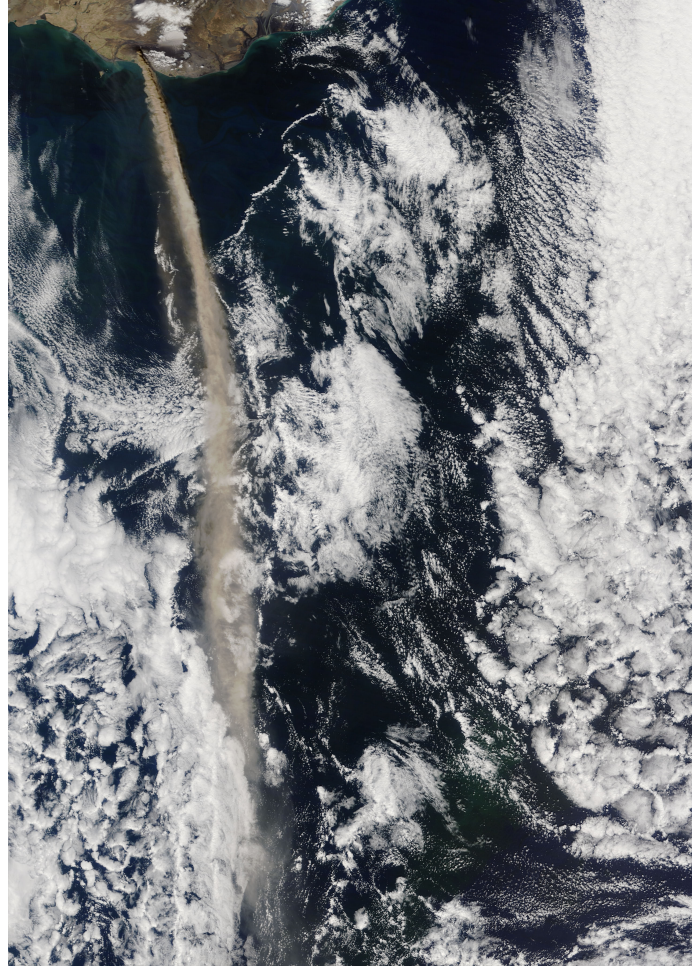
Tracking Volcanic Ash with Satellites



<https://www.nasa.gov/feature/goddard/2016/satellite-data-could-help-reduce-flights-sidelined-by-volcanic-ash>

Iceland's Eyjafjallajökull Volcano – May 11, 2010

Worldview Link: <https://go.nasa.gov/2Fh0bAz>



<https://earthobservatory.nasa.gov/NaturalHazards/view.php?id=43931>

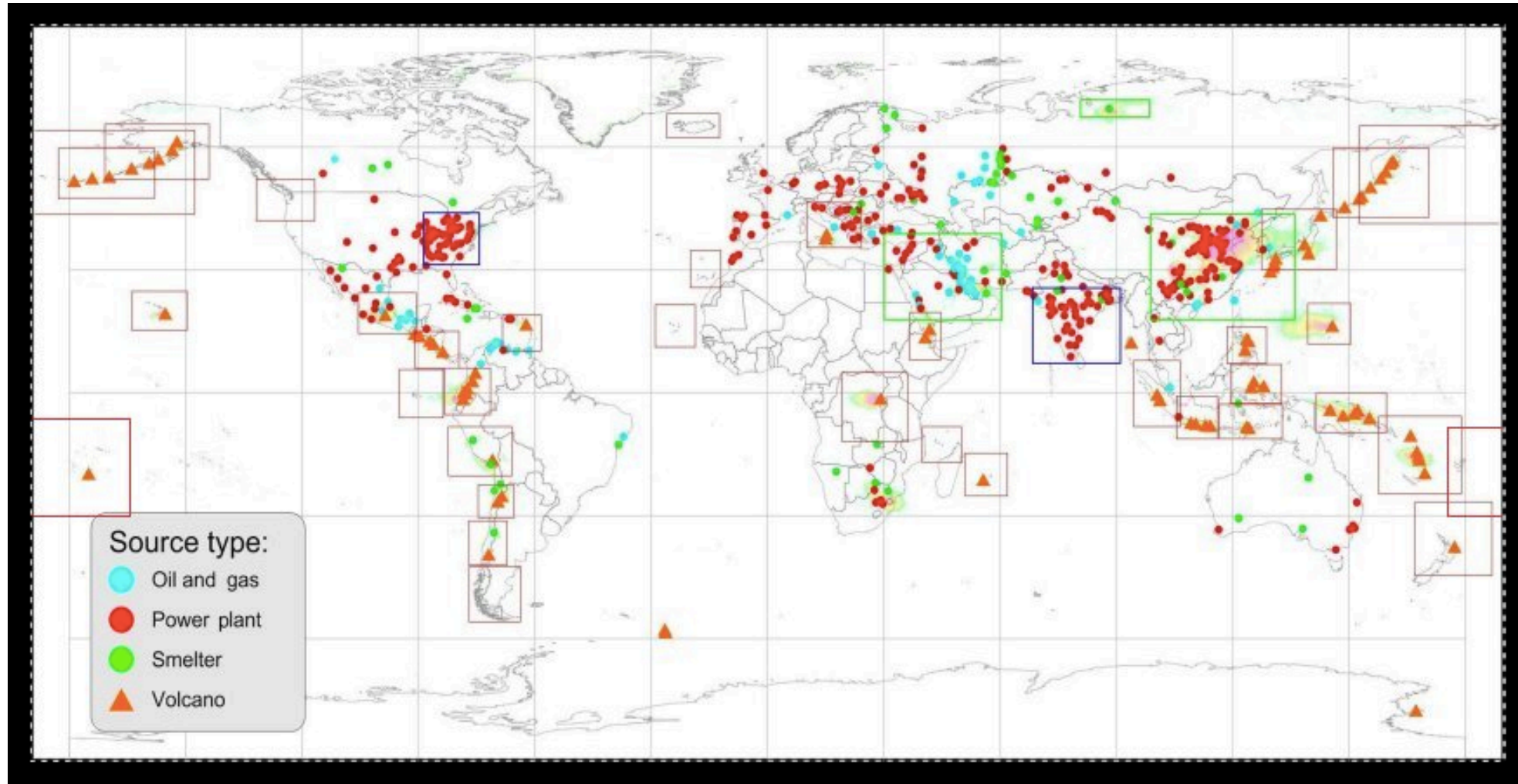
Paluweh Volcano in Indonesia

Worldview Link: <https://go.nasa.gov/2FUdt7d>



Google Search Results with keywords Volcano, NASA

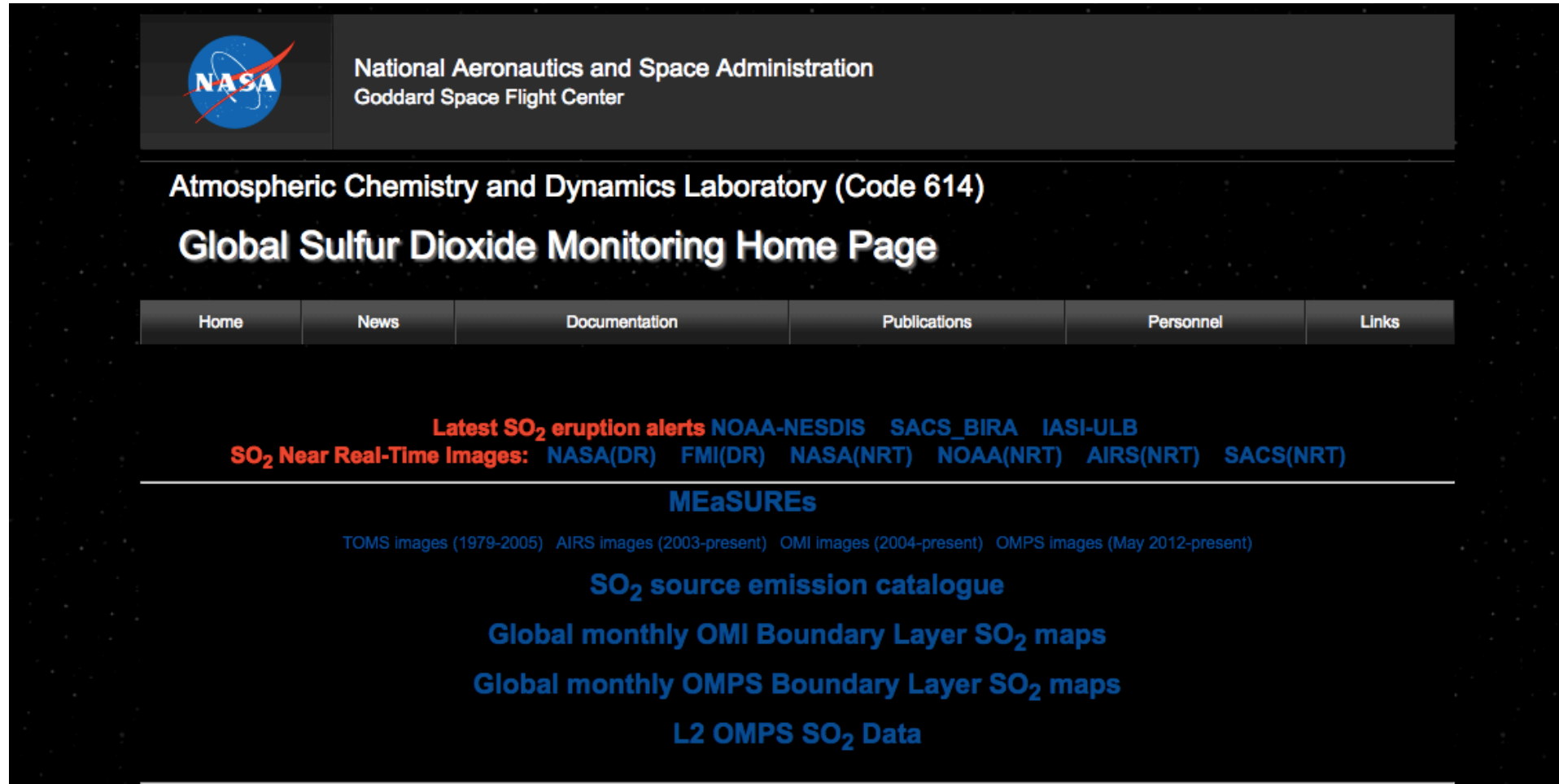
Global Sulfur Dioxide Monitoring



<https://so2.gsfc.nasa.gov/>

Web Tour

<https://so2.gsfc.nasa.gov/>



The screenshot shows the NASA Global Sulfur Dioxide Monitoring Home Page. At the top left is the NASA logo. To its right, the text reads "National Aeronautics and Space Administration" and "Goddard Space Flight Center". Below this, the page title "Atmospheric Chemistry and Dynamics Laboratory (Code 614)" is displayed, followed by the main heading "Global Sulfur Dioxide Monitoring Home Page". A navigation bar contains links for "Home", "News", "Documentation", "Publications", "Personnel", and "Links". Below the navigation bar, there are links for "Latest SO₂ eruption alerts" and "SO₂ Near Real-Time Images", each followed by a list of data sources: NOAA-NESDIS, SACS_BIRA, IASI-ULB, NASA(DR), FMI(DR), NASA(NRT), NOAA(NRT), AIRS(NRT), and SACS(NRT). A section titled "MEaSURES" follows, with a list of data products: TOMS images (1979-2005), AIRS images (2003-present), OMI images (2004-present), and OMPS images (May 2012-present). Below this, there are links for "SO₂ source emission catalogue", "Global monthly OMI Boundary Layer SO₂ maps", "Global monthly OMPS Boundary Layer SO₂ maps", and "L2 OMPS SO₂ Data".

NASA

National Aeronautics and Space Administration
Goddard Space Flight Center

Atmospheric Chemistry and Dynamics Laboratory (Code 614)

Global Sulfur Dioxide Monitoring Home Page

Home News Documentation Publications Personnel Links

Latest SO₂ eruption alerts NOAA-NESDIS SACS_BIRA IASI-ULB
SO₂ Near Real-Time Images: NASA(DR) FMI(DR) NASA(NRT) NOAA(NRT) AIRS(NRT) SACS(NRT)

MEaSURES

TOMS images (1979-2005) AIRS images (2003-present) OMI images (2004-present) OMPS images (May 2012-present)

SO₂ source emission catalogue

Global monthly OMI Boundary Layer SO₂ maps

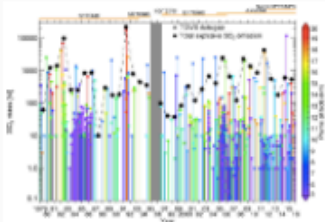
Global monthly OMPS Boundary Layer SO₂ maps

L2 OMPS SO₂ Data

Multi-Satellite Volcanic SO₂ Long-Term Global Database

https://disc.gsfc.nasa.gov/datasets/MSVOLSO2L4_V2/summary

MSVOLSO2L4: Multi-Satellite Volcanic Sulfur Dioxide L4 Long-Term Global Database V2



These data are a part of MEaSUREs 2012 projects. The particular project, "Multi-Decadal Sulfur Dioxide Climatology from Satellite Instruments", is expected to produce SO₂ Earth Science Data Record by means of combining measurements from backscatter Ultraviolet (BUV), thermal infrared (IR) and microwave (MLS) instruments on multiple satellites. The data represent best estimates of the volcanic and anthropogenic contribution to global atmospheric SO₂ concentrations. Since SO₂ is the major precursor of sulfate aerosol, which has climate and air quality impact, SO₂ measurements will contribute to better understanding of the sulfate aerosol distributions and its atmospheric impact."

The released data file is a long-term database of volcanic SO₂ emission derived from ultraviolet satellite measurements from

October 31, 1978, to present.

Data a [...more](#)

Data Access

[Online Archive](#)

[EARTHDATA Search](#)

Product Summary

[Data Citation](#)

[Documentation](#)

Shortname: MSVOLSO2L4

Longname: Multi-Satellite Volcanic Sulfur Dioxide L4 Long-Term Global Database V2

DOI: 10.5067/MEASURES/SO2/DATA402

Version: 2

Format: ASCII

Spatial Coverage: -180.0,-90.0,180.0,90.0

Temporal Coverage: 1978-10-31 to present



Volcanic Cloud Monitoring - NOAA

<http://volcano.ssec.wisc.edu/imagery/view/>

Volcanic Cloud Monitoring — NOAA/CIMSS

[Home](#) [Satellite Imagery](#) [Alerts](#) [Coverage Map](#) [Tutorials](#) [Status](#) [Login](#)

Volcanic Cloud Imagery

Sector: [Use Map](#)
Java 1 km

Instrument:
☒ AHI
☒ MODIS
☒ VIIRS

Satellite:
☐ Aqua
☒ HIMAWARI-8
☐ S-NPP
☐ SNPP
☐ Terra

Image Type:
Ash Loading

End Time:
2018-03-02 19:50:00

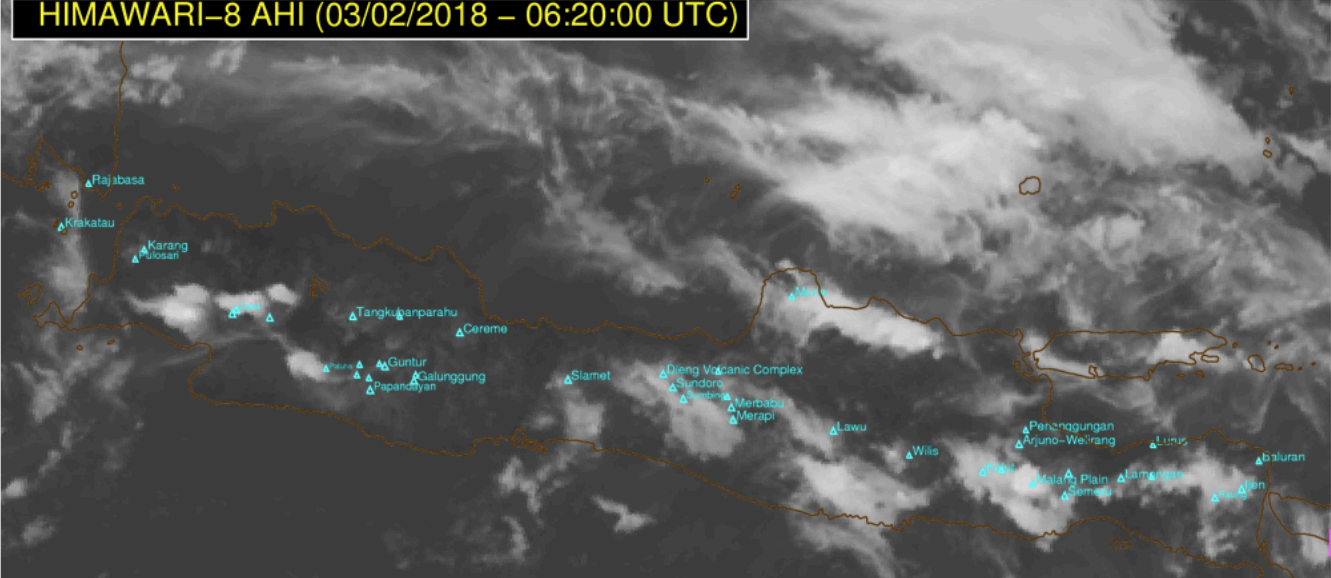
Date Range:
1 day

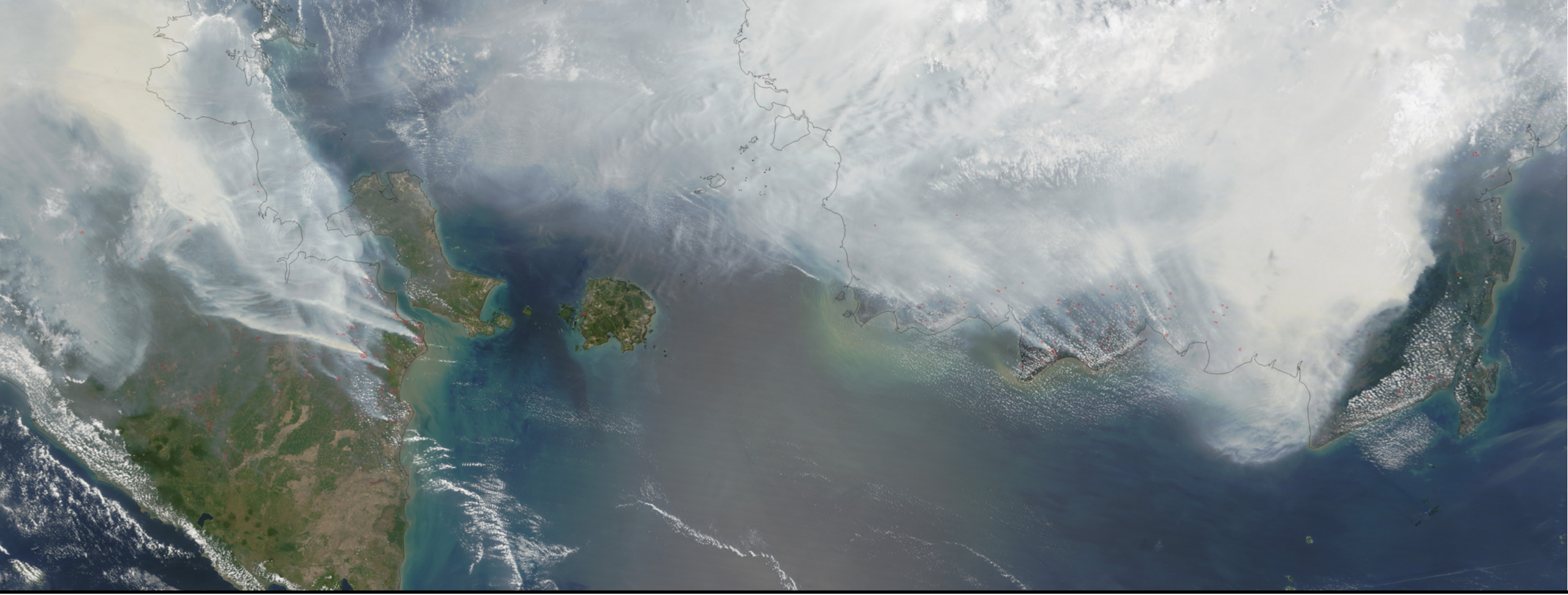
First Image	<	Stop	>	Last Image	Slower	Faster
Rock	Zoom	Download Original	Download Modified	Probe On	Annotate	Draw Points

☐ Lat/Lon Grid ☐ VAAC Bounds ☒ Volcanoes ☒ Map ☒ Annotation

IR Window Imagery and Ash/Dust Loading

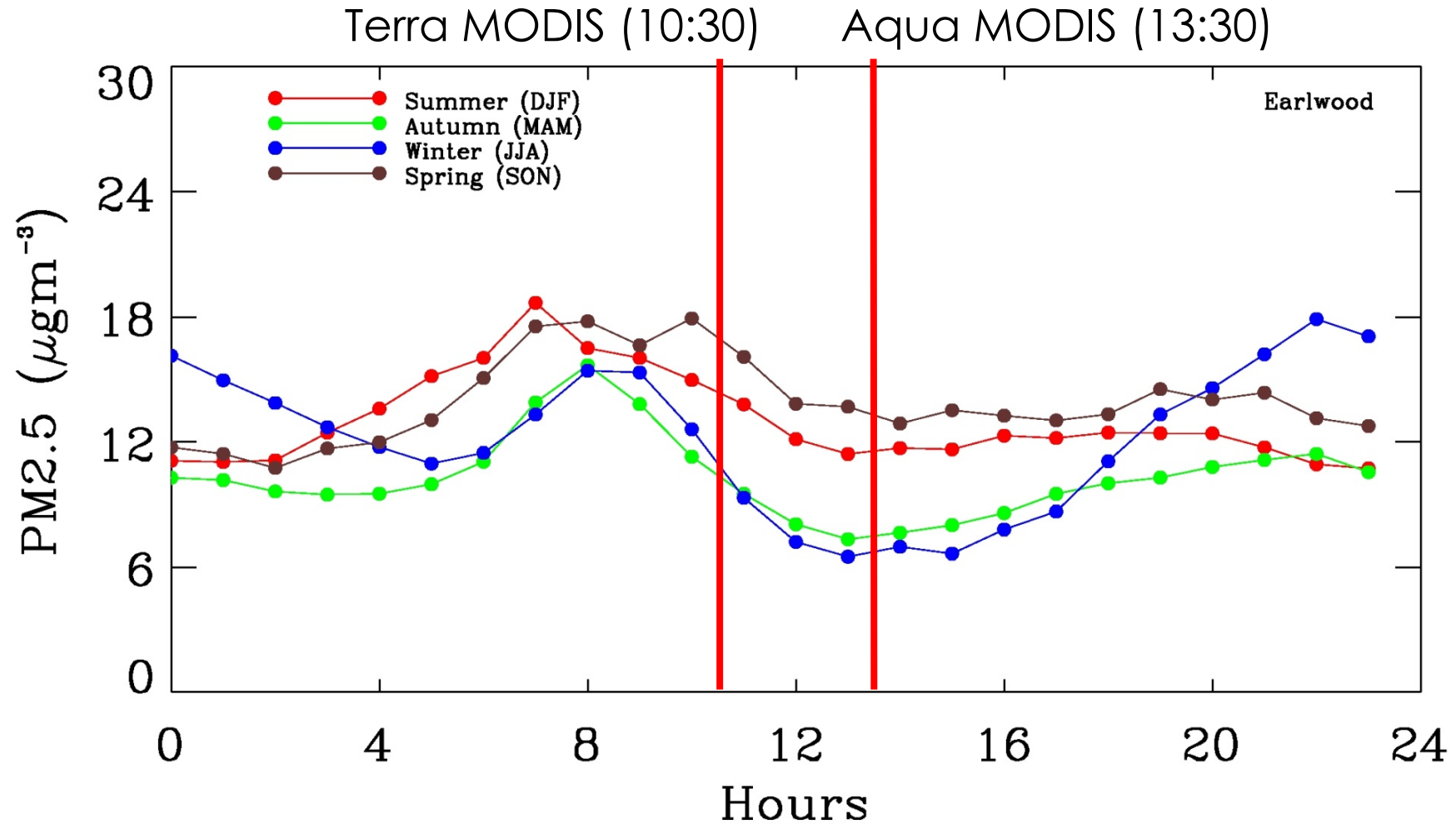
HIMAWARI-8 AHI (03/02/2018 – 06:20:00 UTC)





Geostationary Observations

Polar vs. Geostationary Observations



Gupta et al., 2007

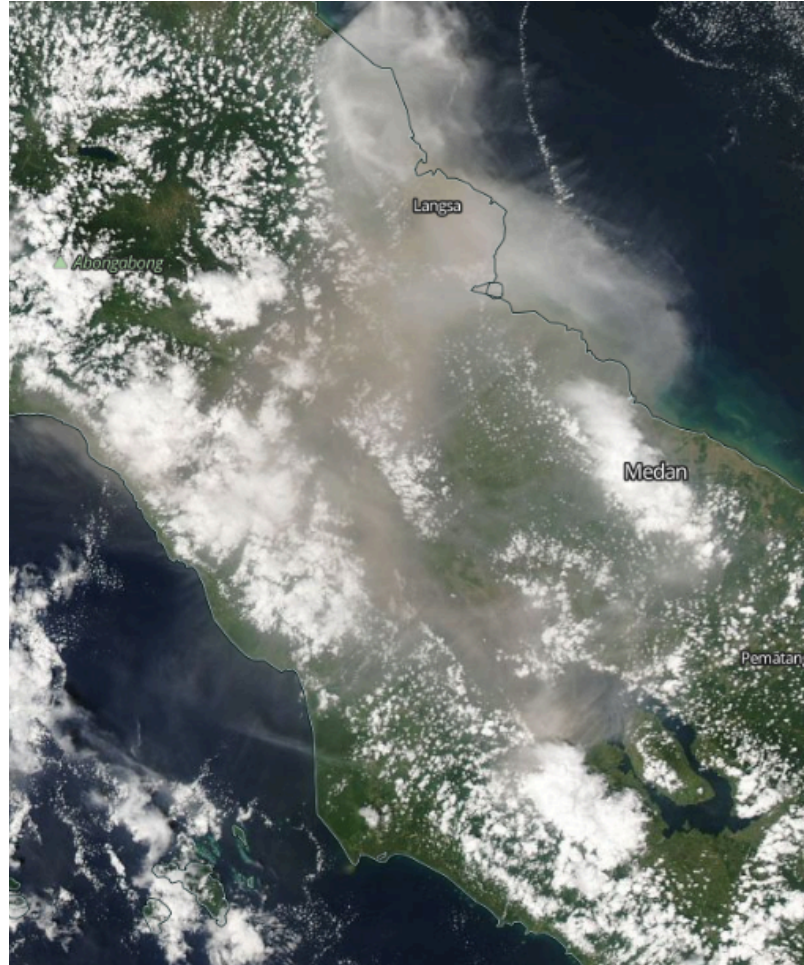


Eruption of Sinabung in Indonesia – Feb 19, 2018 Example

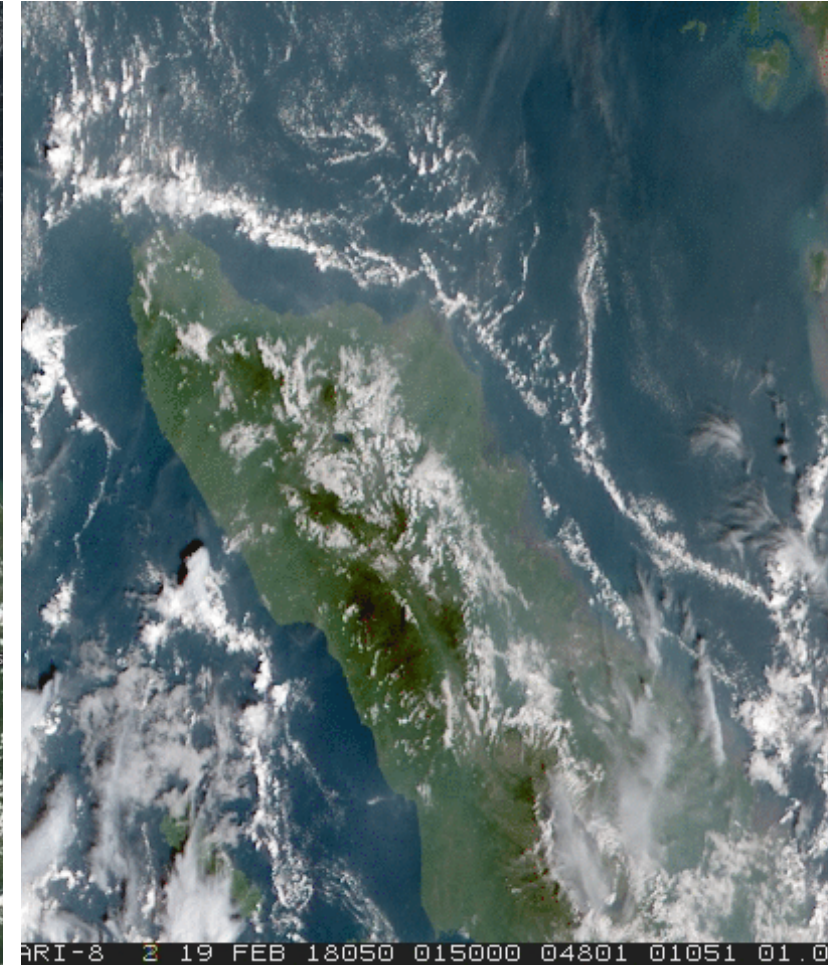
MODIS – Terra



MODIS-Aqua



Himawari-8



http://rammb.cira.colostate.edu/ramsdms/online/loop_of_the_day/himawari.asp and NASA Worldview



Bush Fires in Australia – Nov 15, 2016 Example

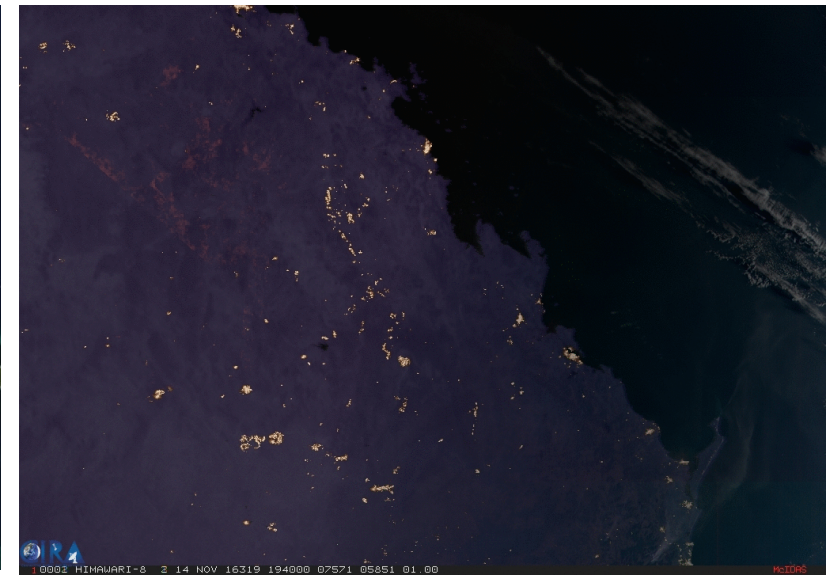
MODIS – Terra



MODIS – Aqua



Himawari-8

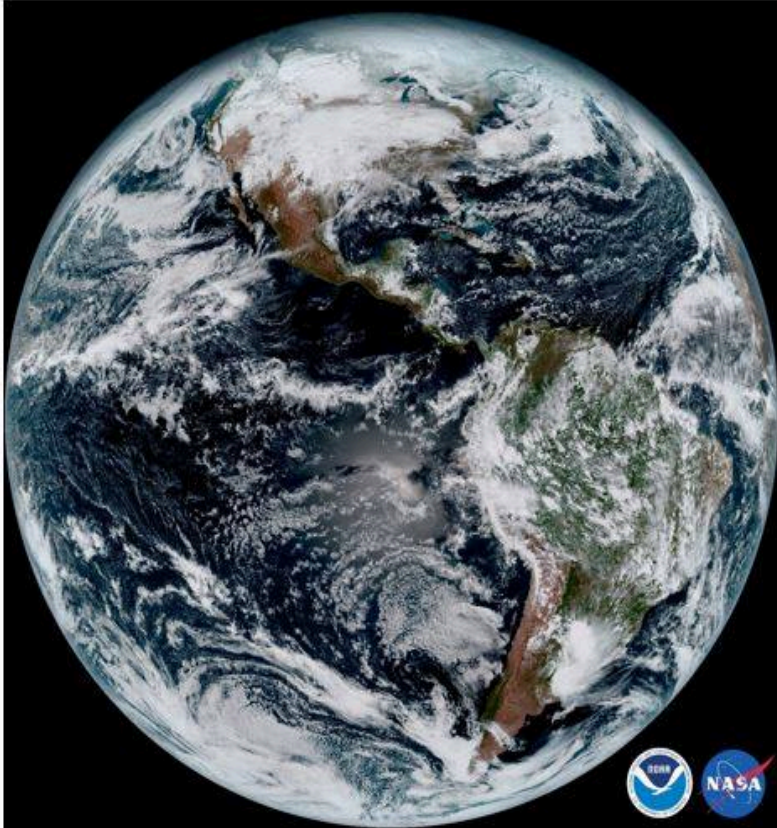


http://rammb.cira.colostate.edu/ramsd/online/loop_of_the_day/himawari.asp and NASA Worldview



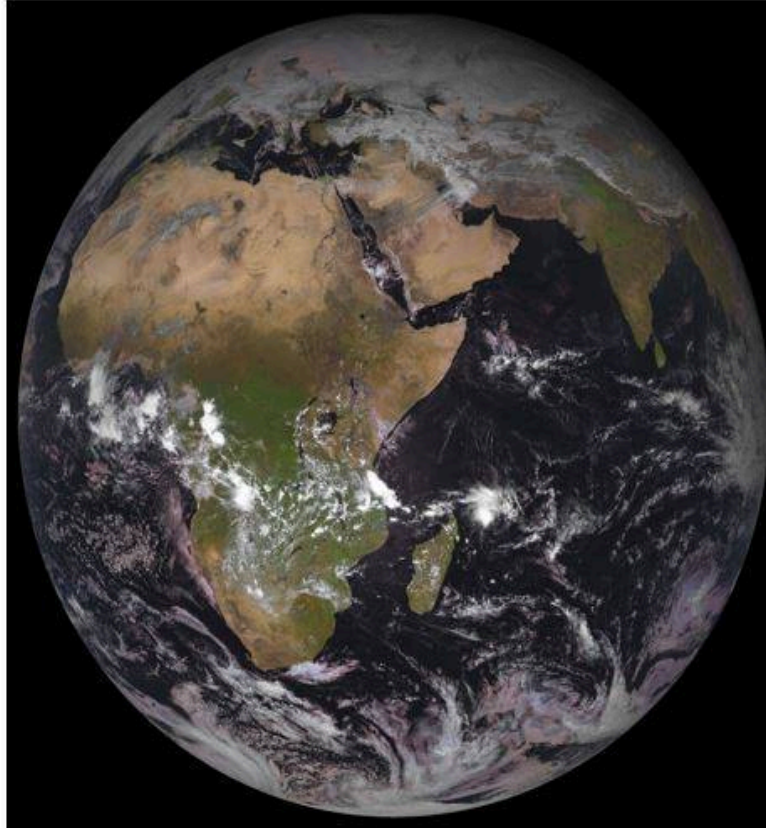
Breaking the Temporal Barrier

The beginning of a new era in satellite remote sensing of air quality



GOES-16

Source: NOAA NESDIS



METEOSAT-8

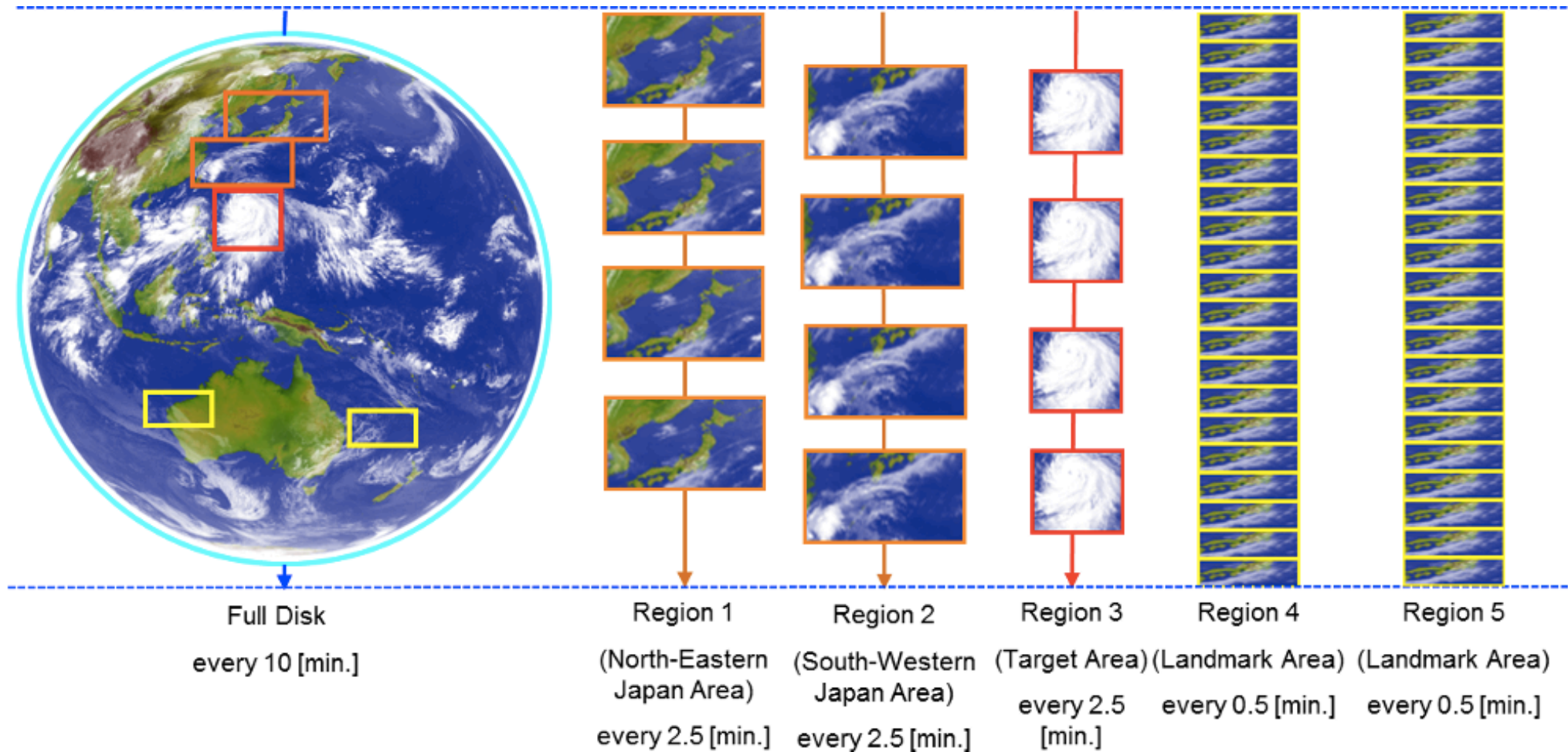


HIMAWARI-9



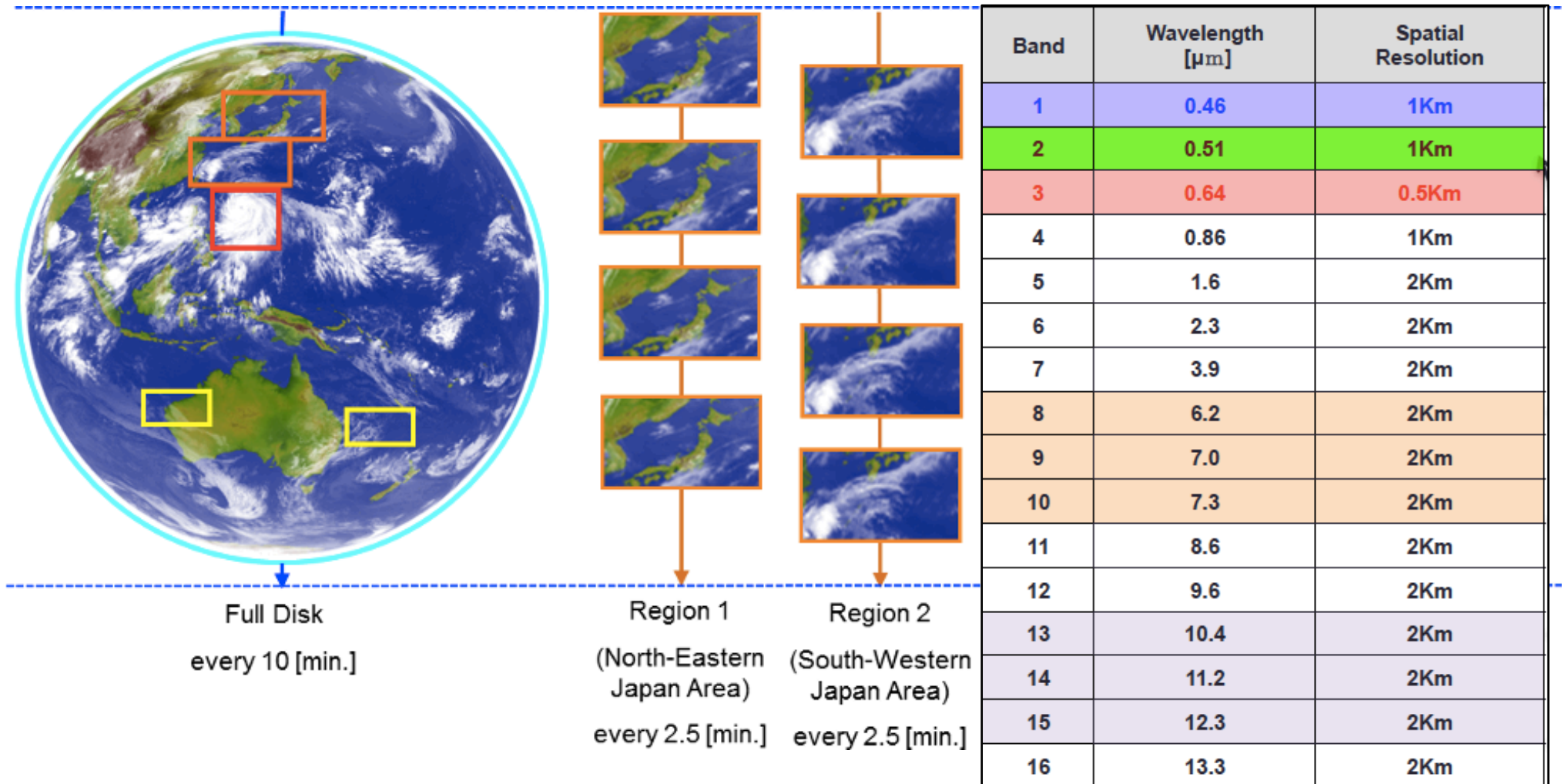
Advanced Himawari Image (AHI)

<http://www.data.jma.go.jp/>



Advanced Himawari Image (AHI) – Spectral Bands

<http://www.data.jma.go.jp/>



Himawari – Slider – Web Tool

<http://rammb-slider.cira.colostate.edu/>

2018-03-05
14:20:00 UTC

Stop (space) < >

☒ (L)oop ☐ (R)ock ☐ Re(v)

Speed

Zoom (+) Zoom (-) Max (Z)oom

☒ (M)aps ☐ Lat/Lo(n) ☐ Slid(e)r

☐ Mouse (D)raw ☐ Clear Drawin(g)s

(S)atellite Himawari-8

Se(c)tor Full Disk

(P)roduct GeoColor (CIRA)

Add (O)verlay Add (O)verlay

of (I)mages 12

(T)ime Step 10 min

GeoColor (CIRA)

☐ Hide

☐ (A)rchived Imagery

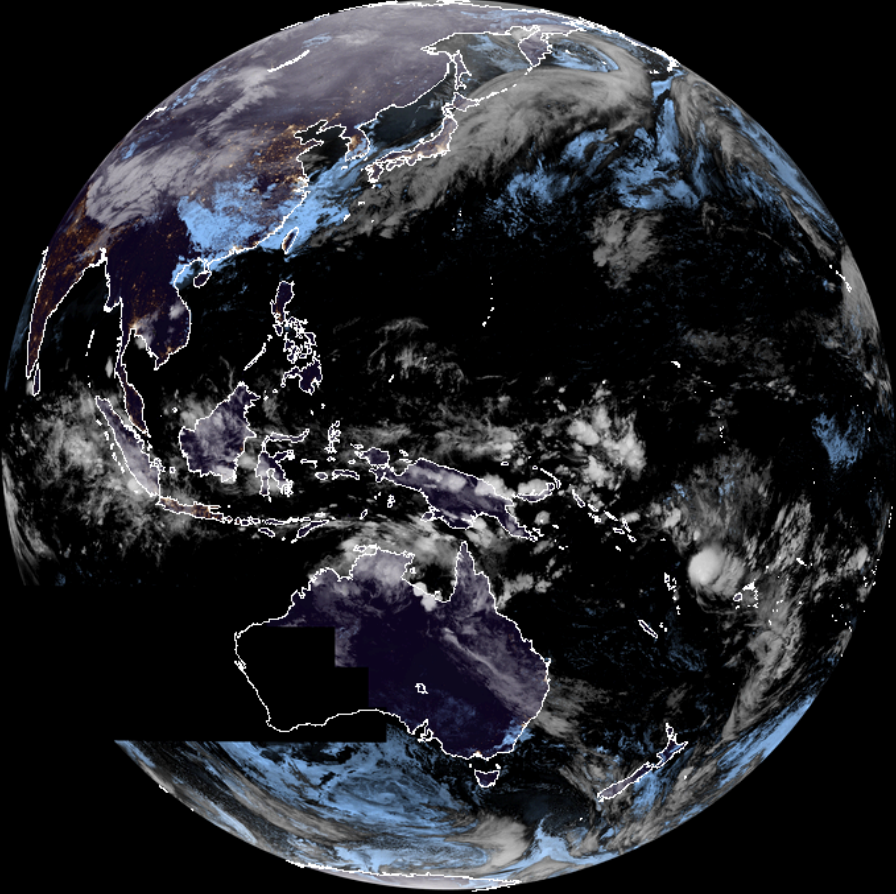
(B)egin D... ... Begin Ti...
End Date... ... End Tim...

Home (y) Share (U)RL Help (?)

[SLIDER by RAMMB / CIRA @ CSU](#)
[Experimental Products Disclaimer](#)

2018-03-05 14:20:00 UTC

(H)ide



CIRA
Connecting Weather and Observations

RAMMB



JAXA Himawari Monitor: P-Tree System

<http://www.eorc.jaxa.jp/ptree/>

JAXA Himawari Monitor
P-Tree System

日本語 Last Update: 05 Mar 2018 15:10:24 UTC

User Registration User Guide

Date: 2018 / 3 / 4 3 : 50~59 UTC Search

10 min 1 hour

-1day -1hour -10min Latest Image +10min +1hour +1day

Layer Menu

Overlay:

- Coastline (1:50m)
- Coastline (1:10m)
- Latitude/Longitude
- Major River

JAXA Products:

- Sea Surface Temperature
- Sea Surface Temperature (Night Mode)
- Aerosol Optical Thickness
- Short Wave Radiation

RGB (Himawari)

Layer Opacity Control

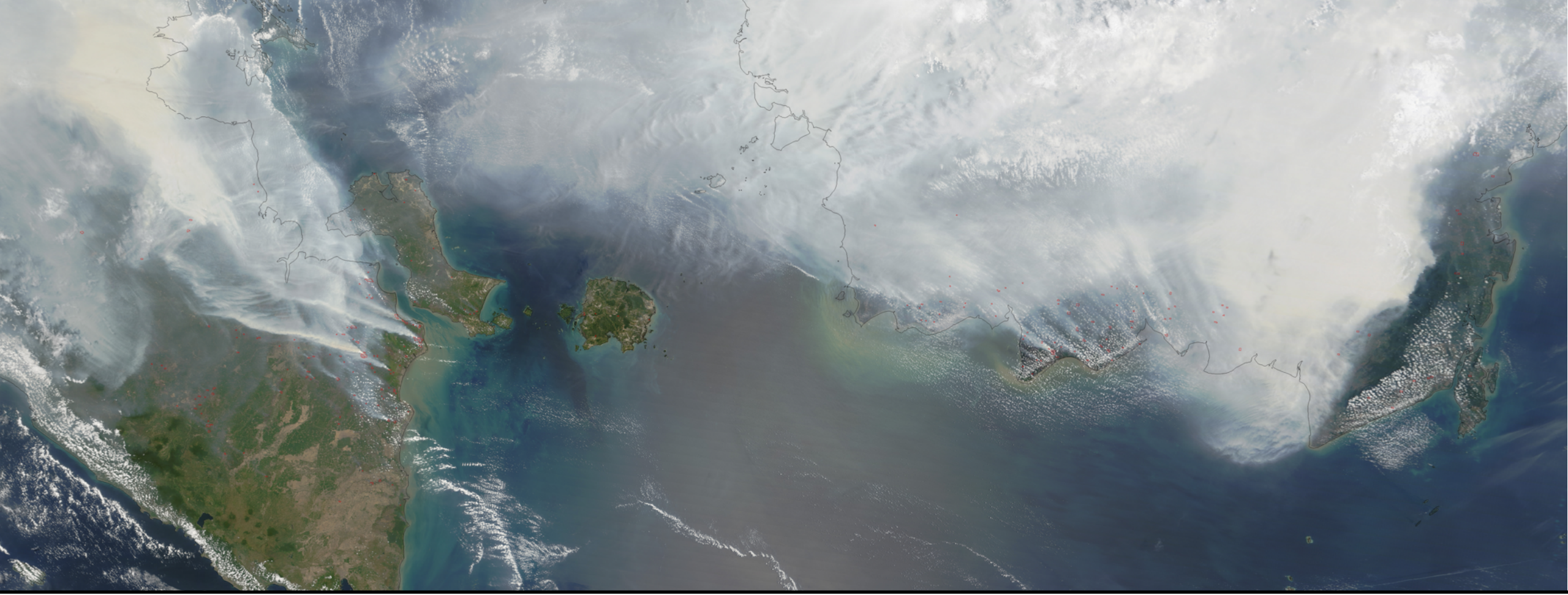
Full Screen

What's New

Feb/08/'18
NEW

Due to the maintenance of the Himawari-8 satellite, all of the Himawari-8 products will be unabailable during the following period.





MERRA-2 Reanalysis

Why data assimilation?

- Models are useful, but have difficulty specifying emissions, microphysical processes, and transport, leading to large uncertainties
- While there are a large number of aerosol sensors, there are still blind spots:
 - Measurements are usually vertically integrated
 - Diurnal cycle is not represented by polar orbiters
- Data assimilation can act as an integrator of model and observational information and a conveyor of past observations



What is reanalysis, and why do we do it?

What

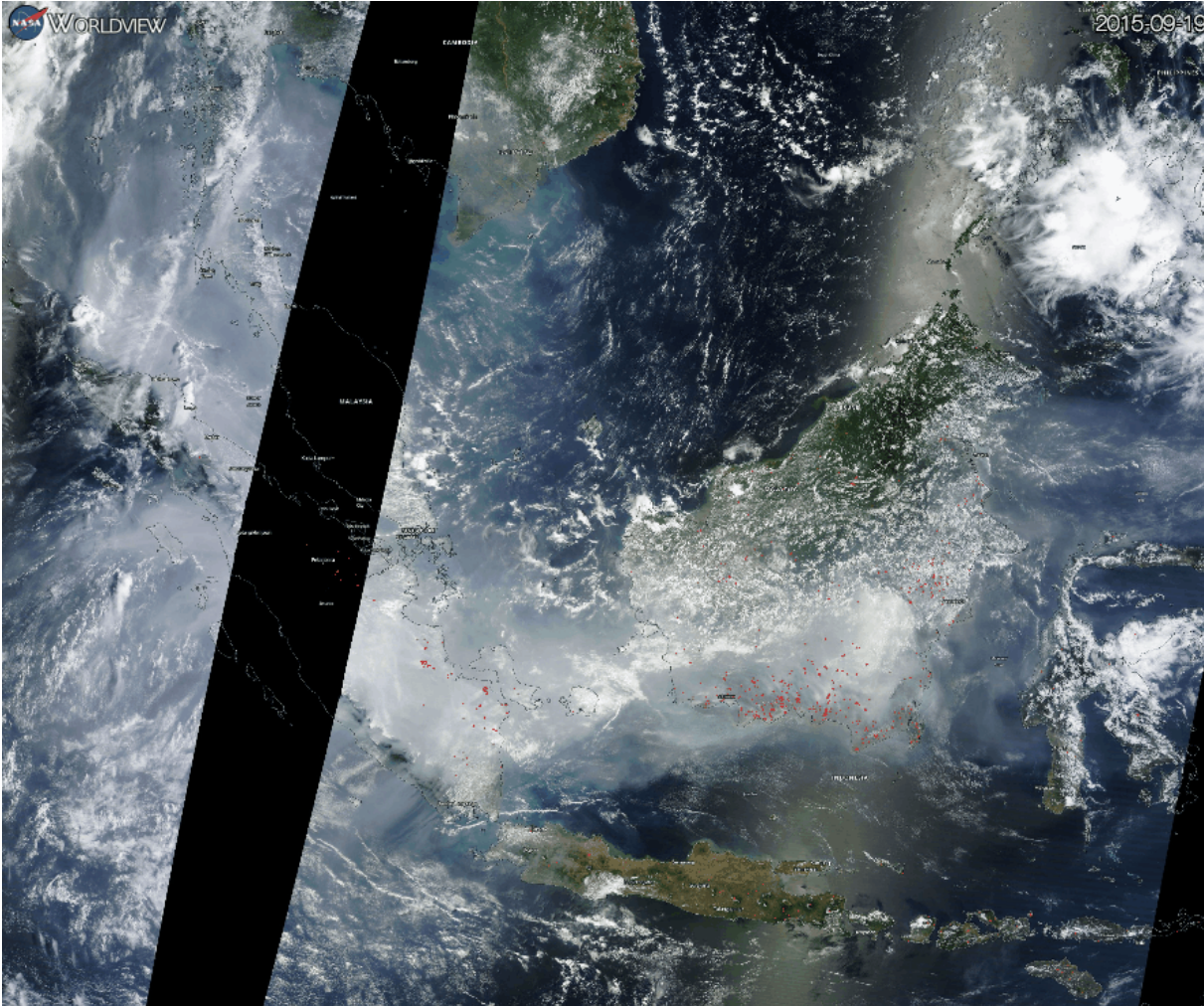
- Relies on models to interpret, relate, and combine different observations from multiple sources
- A consistent reprocessing of Earth system observations using a modern, unchanging data assimilation system
- A successful reanalysis **requires** a good forecast model combined with bias-corrected and quality controlled observations

Why

- Produces multi-decadal, gridded datasets that estimate a large variety of Earth system variables, including ones that are not directly observed
- Has become fundamental to research and education in the Earth sciences



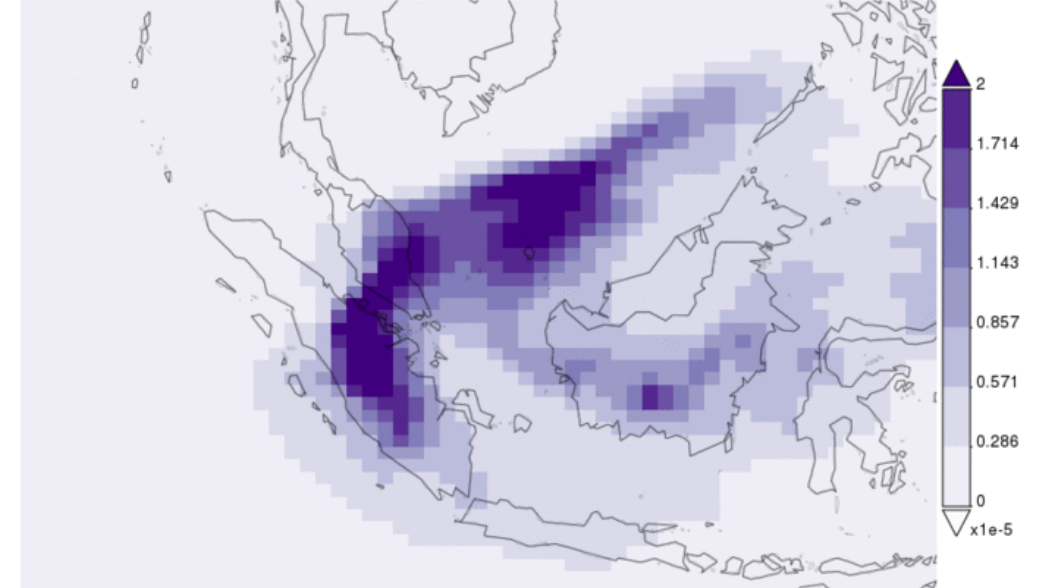
MERRA 2 Reanalysis Example – Sep 2015



MODIS – Terra

MERRA2 – Black Carbon

Black Carbon Column Mass Density, time average hourly 0.5 x 0.625 deg. [MERRA-2 Model M2T1NXAER v5.12.4] kg m⁻² 2015-09-25T23:30:00



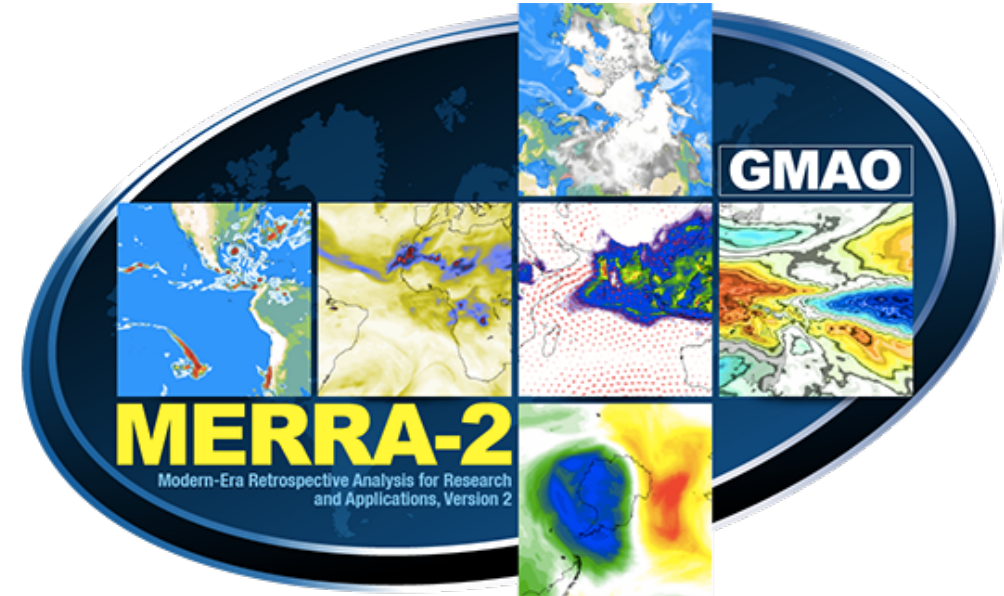
- Selected date range was 2015-09-19 00Z - 2015-09-25 23Z. Title reflects the date range of the granules that went into making this result.



MERRA Reanalysis

<https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/>

- Long-term, model-based analyses of multiple datasets using a fixed assimilation system
 - GEOS (Goddard Earth Observing System Model)
- The **M**odern-**E**ra **R**etrospective analysis for **R**esearch and **A**pplications (MERRA) provides data beginning in 1980 and runs a few weeks behind real-time
- MERRA-2 includes meteorology, stratospheric ozone, and aerosols at a spatial resolution of a $0.5^\circ \times 0.66^\circ$ grid



Source: <https://gmao.gsfc.nasa.gov/reanalysis/>



MERRA -2 Webpage Tour

<https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/>



The screenshot displays the MERRA-2 webpage. At the top, the NASA logo is on the left, and the text "National Aeronautics and Space Administration" and "Goddard Space Flight Center" is in the center. On the right, there is a search bar with a "GO" button and the text "Earth Sciences Division | Sciences and Exploration". Below this is a blue banner with the text "Global Modeling and Assimilation Office" and a "Home" link. A navigation menu follows with tabs for "GMAO MISSION", "WEATHER ANALYSIS & PREDICTION", "SEASONAL-DECADAL ANALYSIS & PREDICTION", "REANALYSIS", "GLOBAL MESOSCALE MODELING", and "OBSERVING SYSTEM SCIENCE". The "REANALYSIS" tab is selected. On the left side of the main content area, there is a sidebar with links: "MERRA-2 Project", "Data Access", "Documentation", "Highlights", "Images", "Videos", "FAQ", "Publications", "Mailing List", "User Metrics", and "Diagnostic Feedback". The main content area features the title "Modern-Era Retrospective analysis for Research and Applications, Version 2" and a "Project Overview" section. The overview text states: "The Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) provides data beginning in 1980. It was introduced to replace the original MERRA dataset because of the advances made in the assimilation system that enable assimilation of modern hyperspectral radiance and microwave observations, along with GPS-Radio Occultation datasets. It also uses NASA ozone observations after 2005. Additional advances in both the GEOS-5 model and the GSI assimilation system are included in MERRA-2. Spatial resolution remains about the same (about 50 km in the latitudinal direction) as in MERRA." Below this, it continues: "Along with the enhancements in the meteorological assimilation, MERRA-2 takes some significant steps towards GMAO's target of an Earth System reanalysis. MERRA-2 is the first long-term global reanalysis to assimilate space-based observations of aerosols and represent their interactions with other physical processes in the climate system. MERRA-2 includes a representation of ice sheets over (say) Greenland and Antarctica." At the bottom of the main content area is a large graphic with the text "GMAO" and "MERRA-2 Modern-Era Retrospective Analysis for Research and Applications, Version 2" over a background of various climate maps.



MERRA-2 Status

- MERRA-2 has officially been released. Data access through the GES DISC:
 - <http://disc.sci.gsfc.nasa.gov/daac-bin/FTPSubset2.pl>
 - <http://disc.sci.gsfc.nasa.gov/uui/#/search/%22MERRA-2%22>
- The MERRA-2 file specification document is available at:
 - <http://gmao.gsfc.nasa.gov/pubs/> under the tab *Office Notes*
- NASA tech memos documenting the MERRA-2 meteorological and aerosol validation exercise will soon be available at:
 - <http://gmao.gsfc.nasa.gov/pubs/> under the tab *Technical Memoranda*

